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EVALUATING ADJUSTABLE PATTERN NOZZLES FOR ENGINE ROOM FIRES ABOARD COAST GUARD CUTTERS

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16. Abstract

The purpose of this project was to: (1) determine whether the Coast Guard should adopt the Akron 3019 nozzle with a matched in-line foam eductor or use it with the existing LP-6 Coast Guard foam eductor for extinguishing Class B engine room fires, (2) identify alternatives to the Akron 3019 nozzle in cases where it is not the best nozzle for a particular class of cutter, (3) document the pressure/flow characteristics of the fire main on specific classes of Coast Guard cutters, and (4) determine the pressure/flow characteristics of the P250 pump.

It is recommended each class of Coast Guard cutter tested should be provided with the Akron 3019 nozzle and a matched in-line eductor (e.g., Akron 2901) for the purpose of extinguishing engine room fires. The Akron 3019 nozzle is also recommended for use on deck fires because of its overall capabilities and its performance under the pressure/flow conditions existing within the different fire mains. The pressure/flow characteristics of the fire main were documented for specific classes of Coast Guard cutters. Pressure/flow characteristics of the P250 pump were determined.

17. Key Words
nozzles, eductors, commercial nozzles, in-line proportioners, marine nozzles, inductor, fire main system

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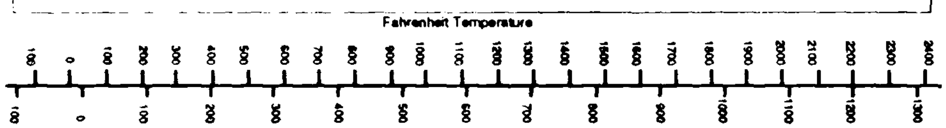
Conversions to Metric Measures

When you know (symbol)	Multiply by	To find (symbol)
Length		
inches (in)	2.540	centimeters (cm)
feet (ft)	30.48	centimeters (cm)
feet (ft)	0.3048	meters (m)
Area		
square inches (in²)	6.452	square centimeters (cm²)
square feet (ft²)	929.0	square centimeters (cm²)
square feet (ft²)	0.09290	square meters (m²)
Volume		
fluid ounces, US (fl oz)	29.57	milliliters (ml); cubic centimeters (cm³)
gallons, US liquid (gal)	3.785	liters (l)
cubic feet (ft³)	0.02832	cubic meters (m³)
cubic yards (yd³)	0.7646	cubic meters (m³)
Mass (weight)		
ounces, avoirdupois (oz)	28.35	grams (g)
pounds (lb)	0.4536	kilograms (kg)
Density		
pounds per cubic inch (lb/in³	27.68	grams per cubic centimeter (g/cm³)
pounds per cubic foot (lb/ft³)	16.02	kilograms per cubic meter (kg/m³)
Pressure		
pounds per square inch (psi)	6895	pascals (Pa); newtons per square meter (N/m²)
pounds per square inch (psi)	0.0703	kilograms per square centimeter (kg/cm²)
pounds per square inch (psi)	51.71	millimeters of mercury (mm Hg) at 0°C
pounds per square inch (psi)	0.06895	bars (10^5 N/m²)
inches of water (in H_2O) at 60°F	1.867	millimeters of mercury (mm Hg) at 0°C
inches of water (in H_2O) at 60°F	248.9	pascals (Pa)
inches of water (in H_2O) at 60°F	0.002489	bars (10^5 N/m²)
inches of mercury (in Hg) at 32°F	3386	pascals (Pa)
inches of mercury (in Hg) at 32°F	0.03386	bars (10^5 N/m²)
Energy		
British thermal units (Btu)	1055	joules (J); newton-meter (Nm)
British thermal units (Btu)	0.2520	kilocalories (kcal)
Thermal Conductance		
Btu / hr - ft² - °F	0.0001356	calories / sec - cm² - °C
Btu / hr - ft² - °F	0.4882	calories / hr - cm² - °C
Btu / hr - ft² - °F	0.0005678	watts / cm² - °C
Heat Flow		
Btu / hr - ft²	0.00007535	calories / sec - cm²
Btu / hr - ft²	0.2712	calories / hr -cm²
Btu / hr - ft²	0.0003154	watts / cm²



Conversions from Metric Measures

When you know (symbol)	Multiply by	To find (symbol)
Length		
millimeters (mm)	0.03937	inches (in)
centimeters (cm)	0.3937	inches (in)
meters (m)	39.37	inches (in)
Meters (m)	3.281	feet (ft)
Area		
square centimeters (cm²)	0.1550	square inches (in²)
square centimeters (cm²)	0.001076	square feet (ft²)
square meters (m²)	1550	square inches (in²)
square meters (m²)	10.76	square feet (ft²)
square meters (m²)	1.196	square yards (yd²)
Volume		
milliliters (ml)	0.03381	fluid ounces, US (fl oz)
liters (l)	0.2642	gallons, US liquid (gal)
liters (l)	0.03531	cubic feet (ft³)
cubic centimeters (cm³)	0.06102	cubic inches (in³)
cubic meters (m³)	35.31	cubic feet (ft³)
cubic meters (m³)	1.308	cubic yards (yd³)
Mass (weight)		
grams (g)	0.03527	ounces, avoirdupois (oz)
grams (g)	0.002205	pounds (lb)
kilograms (kg)	2.205	pounds (lb)
Density		
grams per cubic centimeter (g/cm³)	0.03613	pounds per cubic inch (lb/in³
kilograms per cubic meter (kg/m³)	0.06243	pounds per cubic foot (lb/ft³)
Pressure		
pascals (Pa); newtons per sq. meter (N/m²)	0.000145	pounds per square inch (psi)
bars (10^5 N/m²)	14.50	pounds per square inch (psi)
kilograms per square centimeter (kg /cm²)	14.22	pounds per square inch (psi)
millimeters of mercury (mm Hg) at 0°C	0.01934	pounds per square inch (psi)
millimeters of mercury (mm Hg) at 0°C	0.5357	inches of water (in H_2O) at 60°F
bars (10^5 N/m²)	401.8	inches of water (in H_2O) at 60°F
pascals (Pa)	0.00402	inches of water (in H_2O) at 60°F
pascals (Pa)	0.000295	inches of mercury (in Hg) at 32°F
bars (10^5 N/m²)	29.53	inches of mercury (in Hg) at 32°F
Energy		
kilojoules	0.9478	British thermal units (Btu)
kilocalories	3.968	British thermal units (Btu)
Thermal Conductance		
calories / sec - cm² - °C	7373	Btu / hr - ft² - °F
watts / cm² - °C	1761	Btu / hr - ft² - °F
Heat Flow		
calories / sec - cm²	13270	Btu / hr - ft²

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1.0 BACKGROUND

Currently, adjustable pattern/gallonage nozzles using AFFF are approved on Coast Guard cutters to extinguish Class B (fuel) fires on the flight deck only. An adjustable pattern nozzle using AFFF is not approved for fighting Class B fires in the engine room. For this type of fire, an in-line foam eductor is needed to supply AFFF to the nozzle. The design flow rate of the nozzle and the in-line eductor should be matched to each other and to the actual pressure and flow rate of the fire main to insure that the proper AFFF solution concentration as well as optimum flow and pressure are provided at the nozzle. A nozzle/eductor combination not specifically designed for each other and the existing pressure/flow conditions can still perform satisfactorily in extinguishing fires, but will not function at maximum efficiency.

2.0 OBJECTIVES

The purpose of this project was to determine the optimum nozzle and eductor for Coast Guard cutters with fire mains having different pressure/flow characteristics. The actual fire main pressures and flow rates for each class of cutter are not well documented, therefore this information had to be obtained for the nozzle/eductor evaluation.

The principal objectives were to:

a. Evaluate whether the Coast Guard should adopt the Akron 3019 nozzle with a matched in-line foam eductor or use it with the existing LP-6 Coast Guard foam eductor for extinguishing Class B fires in engine rooms.

b. Identify alternatives to the Akron 3019 nozzle in cases where it is not the best nozzle for a particular cutter class.

c. Document the pressure/flow characteristics of the fire main at a hydrant adjacent to the engine room and at the hydraulically most remote hydrant for the following classes of Coast Guard cutters: 378-foot WHEC, 270 and 210-foot WMEC, 269-foot WAGB, 180-foot WMEC, 157-foot WLM and 140-foot WTGB.

d. Document the pressure/flow characteristics of a portable P250 pump.

3.0 APPROACH

The objectives were achieved by: (1) reviewing previous fire tests reports (Reference 1 and 2) and other publications (Reference 3, 4 and 5) for pertinent information, (2) measuring the water pressure and determining flow rates in the fire mains of different classes of Coast Guard cutters, (3) evaluating the performance of commercial nozzles within the range of measured pressures and flows and (4) conducting fire tests and non-fire tests at the Fire & Safety Test Detachment (F&STD).

4.0 PROCEDURES

4.1 Pressure Measurements and Flow Calculations

For each of the selected Coast Guard cutters representing a class, the water pressure for the fire main was measured at a hydrant located adjacent to the engine room and at the hydraulically most remote hydrant on the main deck. The measurements were taken while operating the main fire pump located outside the engine room. Measurements were also taken for one portable P250 pump. The fire pump inside the engine room was not used, since it is assumed that a fire occurring in this area would make the pump inoperable. At the time these tests were conducted, the cutters did not have the new P250 pump (MOD 1) therefore the existing P250 pump (no model number) was used. The new pump has the same pressure and flow characteristics as the older pump but it also has an electric starter.

The test setup at each hydrant (Figure 1) included two 50 foot lengths of 1 1/2 inch hoseline, two pressure gauges and a nozzle. Eductors were not used in the pressure testing, but were used in the nozzle/eductor testing. Dynamic and static water pressures were measured by gauges at the hydrant and nozzle locations (Figure 1). Two Akron nozzles, the Akron 3019M (designed for a flow of 60 gpm at 100 psig) and the Akron 3019 (designed for a flow of 95 gpm at 100 psig), were used in most of the pressure tests. A third nozzle (designed for a flow of 125 gpm at 100 psig) was used in a few tests but its use was discontinued because the fire mains did not have the pressure for this nozzle to function at its design characteristics.

Nozzles are rated by their manufacturer for a specific flow at a design pressure. The equation $Q = k\sqrt{p}$ (Reference 6)

where

Q= discharge flow, gpm
k= discharge constant
p= hydrant pressure, psig

can be used to calculate the discharge constant for a nozzle. Once the discharge constant has been determined, the formula can be used to calculate the flow corresponding to any pressure

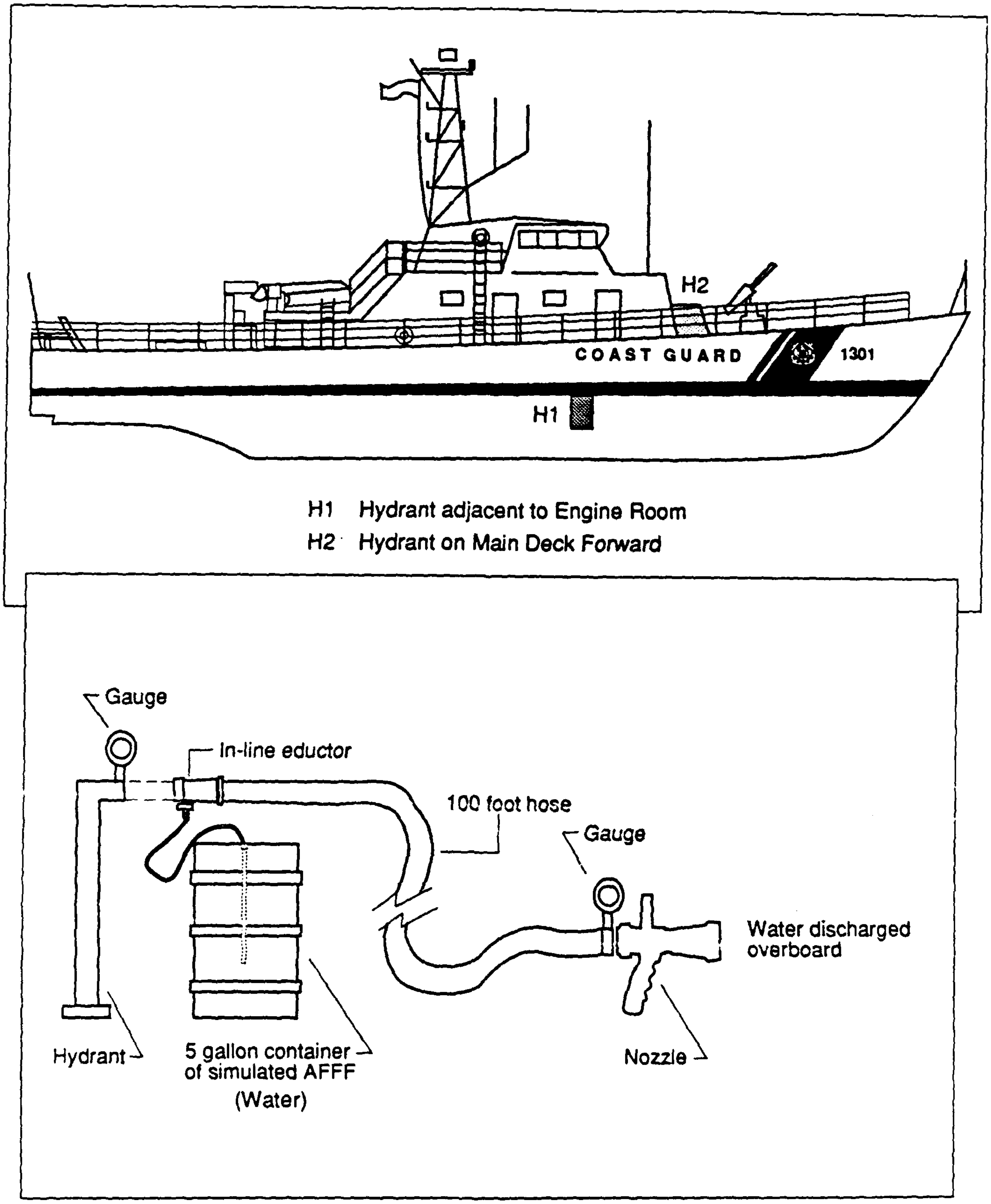

FIGURE 1 Hydrant Location and Test Setup

measured at the nozzle. The water flows shown in Table 1 were calculated using the dynamic nozzle pressures measured on the Coast Guard cutters and each nozzle's calculated discharge constant. Any nozzle with a design pressure and flow of 100 psig/60 gpm, 100 psig/95 gpm, or 100 psig/125 gpm could have been utilized in the pressure testing. The Akron 3019 nozzle (95 gpm) shown in Figure 2 was used in the hands-on measurements to evaluate its performance on the different cutters.

4.2 Nozzle/Eductor Testing

Testing was performed to evaluate nozzle/eductor performance under the flow/pressure conditions measured in Coast Guard cutter fire mains. The Akron 3019M nozzle and the Akron 3019 nozzle were tested with both the LP-6 eductor and the Akron 2900 eductor. The 60 gpm nozzle was included in the testing because the LP-6 eductor carried on Coast Guard cutters is designed for use with a nozzle having approximately this flow rate. A third nozzle with a designed flow of 125 gpm at 100 psig was used in a few tests but was discontinued because when used with the LP-6 eductor the resulting nozzle pressures were sometimes too low for effective firefighting. It is interesting to note that the 60 gpm nozzle, when used with the Akron 2900 eductor, would not draw AFFF (simulated by water) because of the high back pressure created at the outlet side of the eductor. The test nozzles are constructed of non-corrosive materials (brass or bronze) for use in a marine environment and appear to be ruggedly built. The nozzles were represented by the manufacturers as being designed for the effective application of AFFF and also for passing debris with a flush setting. Table 2 shows the flows calculated for the nozzles at various operating pressures. The LP-6 Coast Guard in-line eductor is designed so that a 150 psig inlet pressure will provide a 55 gpm flow of 6 percent AFFF solution. The Akron 2900 eductor is designed so that a 200 psig inlet pressure will provide a 90 gpm flow of a 6 percent AFFF solution. With either eductor, reduced inlet pressure will result in: (a) less water flow, (b) the same educted quantity of AFFF concentrate (a characteristic of that eductor), and therefore (c) an AFFF concentration higher than 6 percent. Table 2 shows calculated flows and AFFF solution concentrations at different inlet pressures for the two eductors used in the tests. This table also shows the same values for a third eductor, the Akron 2901, designed for 125 psig, 70 gpm, 6 percent AFFF solution. The design values for this eductor indicate that it is better suited to match the existing fire main pressures measured on the Coast Guard cutters. Eductors will continue to function over a range of inlet pressures, but will provide the design AFFF concentration at one inlet pressure only.

TABLE 1
NOZZLE PRESSURE/FLOW DATA

COAST GUARD CUTTERS

Cutter Class	Hydrant Location	Nozzle	Rating (gpm/psig)	Hose Lenght (ft.)	Nozzle Flow (gpm)	Static Pressure Hydrant (psig) (*)	Static Pressure Nozzle (psig) (*)	Dynamic Pressure Hydrant (psig)	Dynamic Pressure Nozzle (psig)
378 WHEC	M.F.	Akron 3019M	60/100	100	55	116	114	96	85
	M.F.	Akron 3019	95/100	100	79	116	114	88	70
	A.E.R.	Akron 3019M	60/100	100	54	105	102	90	80
	A.E.R.	Akron 3019	95/100	100	78	105	102	84	68
270 WMEC	M.F.	Akron 3019M	60/100	100	59	111	110	105	96
	M.F	Akron 3019	95/100	100	83	111	110	100	82
	M.F.	Akron 3021	125/100	100	106	111	110	95	72
	A.E.R.	Akron 3019M	60/100	100	61	110	108	110	102
	A.E.R.	Akron 3019	95/100	100	83	110	108	102	82
	A.E.R.	Akron 3021	125/100	100	107	110	108	102	72
269 WAGB	M.F.	Akron 3019M	60/100	50	63	114	114	111	110
	M.F.	Akron 3019M	60/100	100	61	114	114	112	105
	M.F.	Akron 3019	95/100	50	98	114	114	105	95
	M.F.	Akron 3019	95/100	100	90	114	114	106	90
	A.E.R.	Akron 3019M	60/100	50	62	114	114	110	107
	A.E.R.	Akron 3019M	60/100	100	61	114	114	114	105
	A.E.R.	Akron 3019	95/100	50	93	114	114	105	95
	A.E.R.	Akron 3019	95/100	100	90	114	114	107	90
210 WMEC	M.F.	Akron 3019M	60/100	50	60	122	118	107	100
	M.F.	Akron 3019	95/100	50	82	122	118	86	75
	A.E.R.	Akron 3019M	60/100	50	62	128	123	114	105
	A.E.R.	Akron 3019	95/100	50	85	128	123	94	80
	A.E.R.	Akron 3021	125/100	50	93	128	123	80	55
180 WMEC	M.F.	Akron 3019M	60/100	50	59	111	109	104	98
	M.F.	Akron 3019	95/100	50	83	111	109	96	84
	A.E.R.	Akron 3019M	60/100	50	58	112	110	98	94
	A.E.R.	Akron 3019	95/100	50	81	112	110	83	72
157 WLM	M.F.	Akron 3019M	60/100	100	66	135	140	128	120
	M.F.	Akron 3019	95/100	100	85	135	140	124	100
	A.E.R.	Akron 3019M	60/100	100	64	138	140	125	114
	A.E.R.	Akron 3019	95/100	100	56	138	140	113	88
	A.E.R.	Akron 3019M	60/100	100	58	110	110	100	94
	A.E.R.	Akron 3019	95/100	100	85	110	110	95	80
140 WGTB	M.F.	Akron 3019M	60/100	100	67	158	156	140	126
	M.F.	Akron 3019	95/100	100	96	158	156	127	102
	A.E.R.	Akron 3019M	60/100	100	68	158	156	142	130
	A.E.R.	Akron 3019	95/100	100	98	158	156	132	108
P250 Pump	Fantail	Akron 3019M	60/100		61	110	102	110	102
		Akron 3019	95/100		83	110	102	102	82
		Akron 3021	125/100		107	110	104	102	72

M.F. = Main Deck, forward

A.E.R. = Adjacent to Engine Room

(*)(*) = The differences between static pressures at a hydrant and its nozzle is due to the nozzle being located above or below the hydrant during the pressure test.

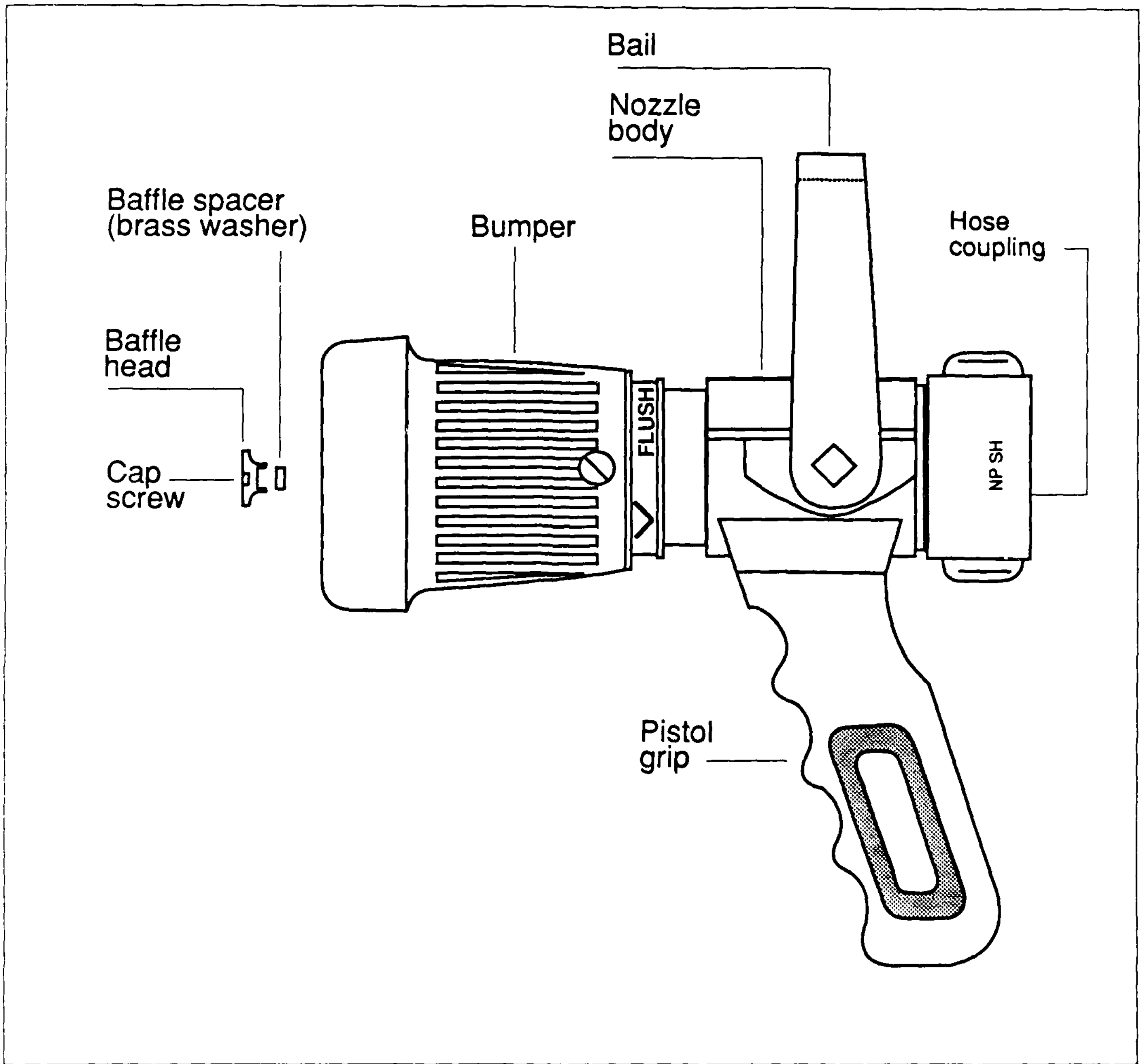

FIGURE 2 Test Nozzles — Akron 3019 / Akron 3019M

TABLE 2

CALCULATED NOZZLE AND EDUCTOR CHARACTERISTICS

NOZZLES

Dynamic Nozzle Pressure (psig)	Akron 3019 Designed for 95 gpm @ 100 psig Water Flow (gpm)	Akron 3019M Designed for 60 gpm @ 100 psig Water Flow (gpm)
120	104	65
100	95	60
80	85	54
60	74	46
40	60	38
20	42	27

EDUCTORS

Dynamic Inlet Pressure (psig)	Akron 2900				Akron 2901				National Foam LP-6			
	Water Flow (gpm)	Conc. Flow (gpm)	Total Flow (gpm)	AFFF Pickup %	Water Flow (gpm)	Conc. Flow (gpm)	Total Flow (gpm)	AFFF Pickup %	Water Flow (gpm)	Conc. Flow (gpm)	Total Flow (gpm)	AFFF Pickup %
200	84	5.4	89	6.0	84	4.4	88	5.0				
180	80	5.4	85	6.3	80	4.4	84	5.2				
175									57	3.3	60	5.5
160	75	5.4	80	6.7	75	4.4	79	5.5				
150									52	3.3	55	6.0
140	70	5.4	75	7.2	70	4.4	74	5.9				
125					66	4.4	70	6.0	50	3.3	53	6.2
120	65	5.4	70	7.7	65	4.4	69	6.3	49	3.3	52	6.3
110	62	5.4	67	8.1	62	4.4	66	6.5	46	3.3	49	6.7
100	59	5.4	64	8.4	59	4.4	63	6.9	44	3.3	47	7.0
90	56	5.4	61	8.8	56	4.4	60	7.3	41	3.3	44	7.5
80	53	5.4	57	9.2	53	4.4	57	7.7	39	3.3	42	8.0
75									37	3.3	40	8.3

Note: Values rounded off to whole numbers except for Concentration Flow and AFFF percent.

4.3 F&STD Testing

Fire tests and non-fire tests were conducted at the Fire and Safety Test Detachment in Mobile, Alabama to evaluate various commercial nozzles for their marine firefighting effectiveness. Nine nozzles were compared to the Coast Guard all-purpose nozzle and its applicator. Most of the nozzles were of the fixed flow rate design while two automatic nozzles (nozzles which automatically adjust their tip opening to the flow) were included in the testing.

The nozzle testing was conducted at different locations on the test vessel ALBERT E. WATTS (Figure 3). Range, pattern and debris tests were conducted on the main deck. LPG (liquefied petroleum gas) fires were also conducted on the main deck to evaluate the operator protection provided by fog patterns of the different nozzles. Compartment fire tests were conducted on the 01 deck to evaluate nozzle effectiveness in interior fires, both for protecting the operator and for control and extinguishment of the fires. These tests, summarized below, are described in detail in Reference 7.

Range tests were conducted at operating pressures of 100, 75 and 50 psig to compare the performance of the different nozzles. A series of lines were painted two feet apart for a distance of 110 feet on the port side of the main deck of the test vessel. Each nozzle was supported on a stand 3-1/2 feet above the deck and elevated 30 degrees above horizontal to provide the greatest range at the different pressures.

Wide fog and narrow fog pattern diameters produced by the nozzles at different pressures were measured on a wooden grid (16 feet wide by 16 feet high with 1 foot divisions). Each nozzle was positioned 3-1/2 feet off the deck and at a distance of 5 feet from the grid for the wide fog measurements and at a distance of 11 feet from the grid for the narrow fog measurements. The wide fog pattern setting marked on each nozzle was used in the wide fog pattern tests, while a standard angle setting of 30 degrees was used for the narrow fog pattern tests. The elevation angle of the nozzles was adjusted to provide the maximum diameter spray at the test distance.

Rust and steel balls were used as debris to determine its effect on nozzle range and performance. Only one type of debris was used per test. The steel balls were 3/8-inch in diameter. The rust was collected from the deck of the test vessel, with particle size ranging between 1/4-inch and 3/4-inch. The procedure for the debris tests involved placing a predetermined quantity of debris into a hoseline leading to the nozzle being tested. Water was then directed through the hose to the nozzle

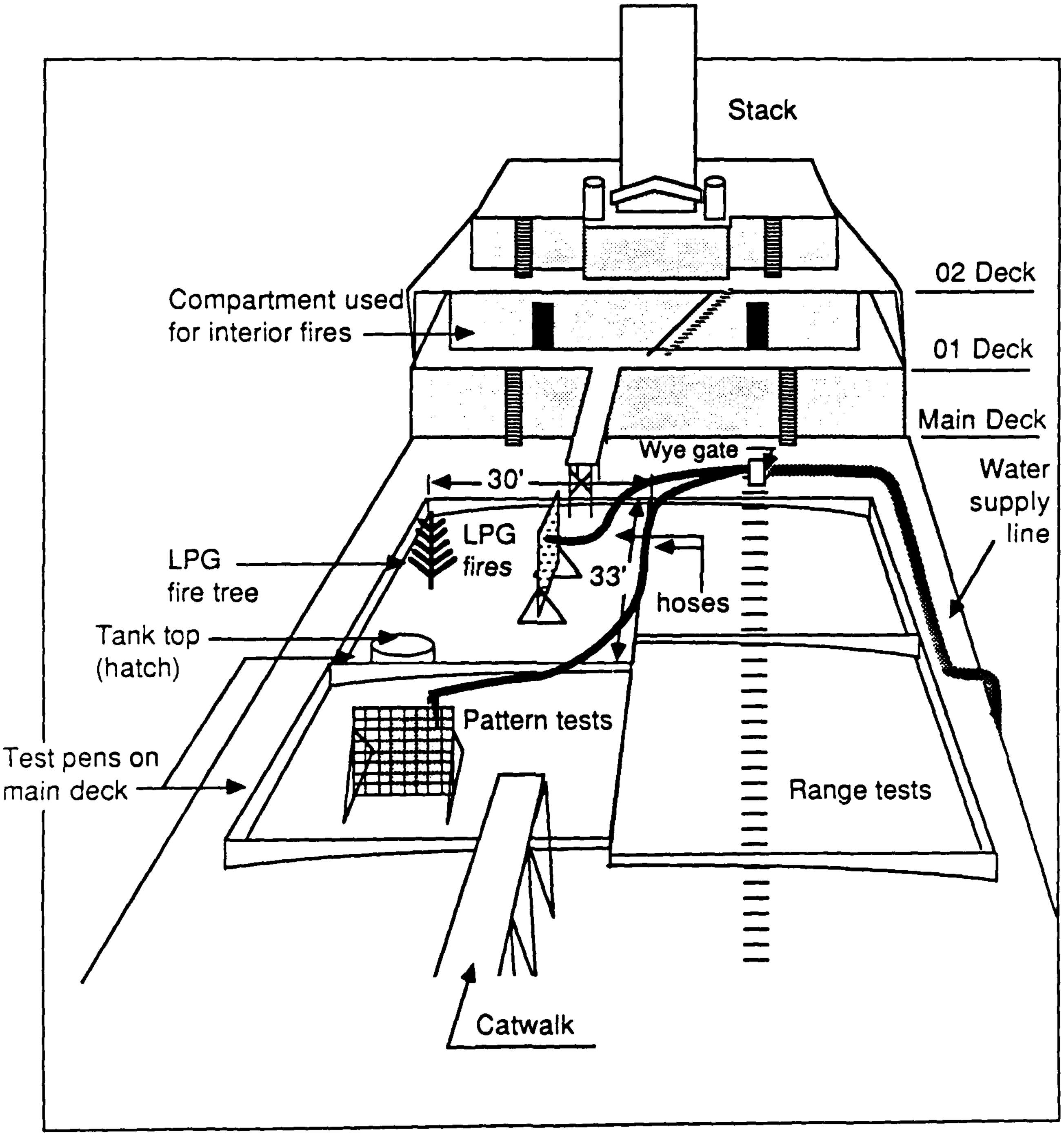

FIGURE 3 Test Areas on Tank Vessel A. E. WATTS

and an attempt was made to clear the nozzle using its flush setting and by turning the nozzle bail on and off. In addition to this test procedure, each nozzle was turned upside down and an attempt was made to pass a single steel ball through each nozzle and out its flush setting. Three scenarios (wide fog pattern, wide fog pattern with AFFF and narrow fog pattern) were tested with various nozzles on the LPG fire setup. An LPG piping tree was used in the testing because it provided a heat source which could be regulated and which was reproducible. Each test nozzle was clamped 3-1/2 feet off the deck and positioned 4 feet away from the LPG tree for the wide fog pattern tests, and 8 feet away for the narrow fog pattern tests. Each nozzle was elevated so that the bottom of the fog spray just touched the deck in front of the LPG tree to prevent flames from sweeping under the spray and endangering the imaginary nozzle operator. Heat flux data was then recorded before and during each fire test at the location of the imaginary nozzle operator behind the protective spray.

The compartment fire tests were conducted on the starboard side of the 01 deck of the test vessel. All combustibles were removed from the test compartment except for the Class B fuel load (10 gallons of marine diesel and one gallon of mineral spirits) used in each test. The fuel was contained in an open steel pen located in the test compartment. Five pre-tests were conducted by firefighters to evaluate various firefighting gear and different techniques for attacking interior fires. Firefighter safety considerations made it necessary to use a stationary nozzle setup for conducting the remaining compartment fire tests. For these tests, each nozzle was mounted 2-1/2 feet off the deck in the passageway and pointed into the test compartment.

5.0 RESULTS

5.1 Pressure Measurements and Flow Calculations

Pressure measurements were taken for the fire mains on seven classes of Coast Guard cutters. Pressure measurements were also taken for a portable P250 pump on two of the cutters. The P250 pumps tested were of the older type (those with no MOD number). None of the selected cutters had received the new P250 pumps (MOD 1) being distributed. Flows were calculated from the measured pressures by means of the formula shown in section 4.1.

5.1.1 Fire Mains on Coast Guard Cutters

Table 1 shows measured pressures and calculated flows for the fire main on board the different classes of cutters. The data includes static and dynamic pressures measured at the hydrants and nozzles as summarized from Appendices A-G. Static pressures reflect no water flow; dynamic pressures were recorded with water flowing. The difference in static pressures at a hydrant and its test nozzle is due to the nozzle being located several feet above or below the hydrant while the testing was

conducted. The difference in dynamic pressure at a hydrant and its test nozzle is due to friction loss in the hose and any difference in elevation between the eductor and the nozzle while the testing occurred.

The dynamic nozzle pressure/flow values for the two test locations ranged from 80-130 psig/54-68 gpm for a 60 gpm nozzle, 70-108 psig/79-98 gpm for a 95 gpm nozzle and 55-72 psig/93-107 gpm for a 125 gpm nozzle. These pressures correspond to water straight stream ranges of approximately 90 to 115 feet. This data shows that the fire pumps on each class of cutter provide sufficient pressure/flow to effectively utilize nozzles designed for 60, 95 or 125 gpm, when an eductor is not used.

It is interesting to note that the lowest measured pressure (80 psig) for the 60 gpm nozzle provides 54 gpm, whereas the lowest measured pressure (70 psig) for the 95 gpm nozzle provides 79 gpm. The 95 gpm nozzle provides an increase of 46 percent in water flow available for extinguishment at the cost of 10 psig (12 percent) pressure loss. Within this pressure range, a 12 percent pressure loss is a good exchange for 46 percent more water for extinguishment. The use of the 125 gpm nozzle provides even more water for extinguishment than the 95 gpm nozzle, but it also suffers an even greater pressure loss of 25 to 48 percent when compared to the pressure of the 60 gpm nozzle.

Table 3A shows the nozzle pressure, flow and range of the three nozzles when considering the pressure/flow conditions existing on the Coast Guard cutters tested. For a fire on the main deck, range would be a more important nozzle characteristic than for a fire in the engine room. This table clearly shows that the 95 gpm nozzle has the greater range of the nozzles, and a flow which is a good compromise as being above that of the 60 gpm nozzle and slightly below the 125 gpm nozzle.

5.1.2 Portable Pump (P250)

A P250 pump was tested on the fantail of the 270-foot WMEC. The data listed in the lower part of Table 1 indicates that the pump is capable of producing a flow of 61 gpm at a pressure of 102 psig, a flow of 83 gpm at a pressure of 82 psig and a flow of 107 gpm at a pressure of 72 psig through nozzles rated respectively at 60, 95 and 125 gpm at 100 psig. These measurements were taken without an eductor in the test setup. At pressures of 72 to 102 psig, the water stream range of the test nozzles is approximately 70 to 100 feet. This range would be more than adequate for interior firefighting.

TABLE 3A

CHARACTERISTICS OF NOZZLES FOR DECK FIRES

Static Nozzle Pressure on Main Deck for Cutters Tested (psig)	Nozzle & Rating (gpm/psig)	Dynamic Nozzle Pressure (psig)	Nozzle Flow (gpm)	Range Straight Stream (feet)
109 – 156	Akron 3019M 60/100	85 – 126	55 – 67	78 – 103
	Akron 3019 95/100	70 – 102	79 – 96	90 – 108
	Akron 3021 125/100	55 – 72	93 – 107	82 – 94

TABLE 3B

CHARACTERISTICS OF NOZZLES/EDUCTORS FOR ENGINE ROOM FIRES

Static Nozzle Pressure Near Engine Room for Cutters Tested (psig)	Nozzle/Eductor	Dynamic Nozzle Pressure (psig)	Nozzle Flow (gpm)	Range st st (feet)	Range nfog* (feet)	AFFF Concentration (%)
108 – 156	Akron 3019/Akron 2901	42 – 60	61 – 74	48 – 60	36 – 40	7.1 – 5.9
	Akron 3019/LP-6	22 – 32	44 – 54	27 – 31	28 – 34	7.5 – 6.1
	Akron 3019M/LP-6	48 – 80	42 – 54	60 – 75	40 – 46	7.8 – 6.1

* st st = straight stream

nfog = narrow fog

5.2 Nozzle/Eductor Testing

Fire Mains on Coast Guard Cutters

The following paragraphs refer to data collected at the hydrant adjacent to the engine room. Similar conclusions may be drawn from data collected at the hydrant located forward on the main deck.

The data collected aboard the cutters is contained in Appendices A-G. An overview of the combined data for each class of cutter is shown in Table 4. This table lists the nozzle pressure, flow and AFFF concentration provided by the nozzle/eductor combinations tested on each class of cutter. Pressure at the nozzle was measured by a pressure gauge (Figure 1) installed behind the nozzle in the hoseline setup. The flow was then calculated using the formula in section 4.1 with the previously calculated nozzle constant. The suction tube of the eductor was placed in a five gallon pail marked off in 1 gallon increments and containing water instead of AFFF. The quantity of water (simulating AFFF) drawn from the pail in one minute was measured. The concentration of the AFFF solution through the nozzle was calculated by dividing the flow of simulated AFFF (gpm of water) drawn from the 5 gallon pail by the solution flow calculated through the nozzle. Water was used to simulate AFFF concentrate because actual AFFF solutions could not be discharged from the Coast Guard cutters into the water where they were docked. Both UL 162 (Reference 8) and NFPA 11C (Reference 9) use water in similar AFFF concentration testing.

An examination of the data in Table 4 shows that a 60 gpm nozzle with the LP-6 eductor had operating pressures of 48 to 80 psig and flow rates of 42 to 54 gpm. A 95 gpm nozzle used with the LP-6 provided operating pressures of 22 to 32 psig and flow rates of 44 to 54 gpm. The data shows that the 60 gpm nozzle had up to 2 1/2 times the pressure as the 95 gpm nozzle when using the LP-6 eductor. Both nozzles provided similar flow rates with this eductor. This is to be expected, since the eductor controls the flow. The same flow is going through the eductor but the pressure is greater at the 60 gpm nozzle due to its smaller tip opening. The 95 gpm nozzle with the LP-6 eductor did produce lower pressures with less range, but because it provides the same application rate, it can extinguish the same size fire if the range is adequate to reach the blaze. The range (34 feet at 22 psig) produced by the 95 gpm nozzle is not considered ideal, but it is adequate for the fire scenario being considered.

This data also indicates the degree to which the fire pump capacity meets the design value of the LP-6 eductor. On two cutters (157-foot WLM and 140-foot WTGB), the fire main pressure was almost sufficient (54 gpm/6.1% AFFF) to reach the design value of the LP-6 eductor. The fire pump capacity of the

TABLE 4

NOZZLE/EDUCTOR DATA FOR CUTTER CLASSES

Cutter Class	Pump Capacity Flow (gpm)	Pump Capacity Pressure (psig)	Hydrant Adjacent to Engine Room: Nozzle/Eductor Akron 3019M/LP-6 (60 gpm) Dynamic Nozzle Pressure (psig)	Flow (gpm)	AFFF Conc. %	Nozzle/Eductor Akron 3019/LP-6 (95 gpm) Dynamic Nozzle Pressure (psig)	Flow (gpm)	AFFF Conc. %	Nozzle/Eductor Akron 3019/Akron 2900 (95 gpm) Dynamic Nozzle Pressure (psig)	Flow (gpm)	AFFF Conc. %	Hydrant, Main Deck Forward: Nozzle/Eductor Akron 3019M/LP-6 (60 gpm) Dynamic Nozzle Pressure (psig)	Flow (gpm)	AFFF Conc. %	Nozzle/Eductor Akron 3019/LP-6 (95 gpm) Dynamic Nozzle Pressure (psig)	Flow (gpm)	AFFF Conc. %	Nozzle/Eductor Akron 3019/Akron 2900 (95 gpm) Dynamic Nozzle Pressure (psig)	Flow (gpm)	AFFF Conc. %
378 WHEC	500	100	48	42	7.8	22	44	7.5	42	61	8.8	52	46	7.2	22	44	7.5	40	60	9.0
270 WMEC	500	125	52	43	7.7	22	44	7.5	46	64	8.4	52	43	7.7	25	48	6.9	42	63	8.6
269 WAGB	300	100	55	44	7.5	22	45	7.3	55	70	7.7	55	44	7.5	22	45	7.3	55	70	7.7
210 WMEC	250	121	57	45	7.3	23	46	7.2	54	70	7.7	50	42	7.9	22	45	7.3	50	67	8.1
180 WMEC	100	104	61	47	7.0	23	46	7.2	45	64	8.4	61	47	7.0	25	48	6.9	45	64	8.4
157 WLM	250	125	81	54	6.1	33	54	6.1	52	71	7.6	81	54	6.1	33	54	6.1	56	72	7.5
140 WGTB	500	145	80	54	6.1	32	54	6.1	60	74	7.3	80	54	6.1	32	54	6.1	60	74	7.3

remaining five cutter classes tested was insufficient to reach the design point of the LP-6 eductor. The low flows and resulting high percent AFFF solutions for the LP-6 eductors indicate that the fire pumps are not capable of producing sufficient inlet pressure to achieve the design conditions of the eductor.

The data in Table 4 indicates that for the different classes of cutters, the 60 gpm nozzle/LP-6 eductor combination had nozzle pressures which ranged from 48 to 81 psig whereas the 95 gpm nozzle/Akron 2900 eductor combination had nozzle pressures which ranged from 42 to 60 psig. When changed to percentages, this shows that the nozzle pressures of the 60 gpm nozzle/LP-6 combination ranged up to 56 percent higher than the nozzle pressures for the 95 gpm nozzle/Akron 2900 eductor.

The data also shows that for the different classes of cutters, the 95 gpm nozzle/Akron 2900 eductor combination had flows which ranged from 61 to 74 gpm whereas the 60 gpm nozzle/LP-6 eductor combination had flows which ranged from 42 to 54 gpm. When changed to percentages, this shows that the flows for the 95 gpm nozzle/Akron 2900 eductor combination ranged from 31 to 59 percent higher than flows for the 60 gpm nozzle/LP-6 eductor combination.

The 95 gpm nozzle/Akron 2900 eductor combination (with the flow available to cover and extinguish 31 to 59 percent more fire) would be preferred since its nozzle pressures (42 to 60 psig) produces ranges (minimum 48 feet on straight stream and 36 feet on narrow fog) which appear quite adequate for interior use against engine room fires. The AFFF solutions for the 95 gpm nozzle/Akron 2900 eductor combination are above the optimum design concentration of 6 percent (7.3 to 9 %). This can be corrected by using an eductor (Akron 2901) which has the same flow features as the Akron 2900 but was modified to provide a more optimum AFFF concentration for the inlet pressures available on the cutter classes investigated. The Akron 2901 eductor at 125 psig inlet pressure will flow 70 gpm of a 6 percent AFFF solution. The Akron 2901 eductor, even when operating slightly below its design point, will produce AFFF solutions which are less wasteful than those from the LP-6 eductor, as its design is 150 psig/55 gpm for a 6 percent AFFF solution. Inlet pressures recorded on the different cutter classes ranged from 140 to 84 psig and therefore are closer to the design pressure of the Akron 2901 eductor (125 psig) than that of the LP-6 eductor (150 psig).

An eductor intended for use aboard all the cutter classes should have a design point that is near the upper limit of the pressures measured on the cutters. If this condition is met, the inlet pressure will not exceed the design pressure of the eductor and thus AFFF concentrations of less than 6 percent will not be produced. NFPA 412 (Reference 10) recommends that an AFFF concentration should not drop below 5.5 percent nor rise above 8

percent when used from handlines. If an error occurs in the concentration of the AFFF solution, the error should be on the rich side (in the 6 to 8 percent range) rather than on the lean side (below 5.5 percent) in order to retain the foam's design characteristics (Reference 10).

Aboard cutters, a minimum of 105 psig static pressure at a hydrant will ensure satisfactory performance of the 95 gpm nozzle/Akron 2901 eductor combination, provided that no obstructions exist in the fire main to reduce the flow to that hydrant.

Portable Pump (P250)

The P250 pump data in Appendix B indicates results similar to those obtained for the nozzle/eductor combinations investigated in the fire main testing. That is, the 60 gpm nozzle/LP-6 eductor combination provides approximately 2 1/2 times the nozzle pressure provided by the 95 gpm nozzle/LP-6 eductor combination. The range provided by the 95 gpm nozzle/LP-6 eductor combination corresponds to a range of 34 feet on a straight stream setting and a range of 28 feet on narrow fog pattern setting. On the main deck this is probably insufficient range, but in the passageway and stairs leading to the engine room it would be sufficient. The flow through the eductor is the same in both cases; therefore since the patterns are not effected and providing that the range is sufficient to reach the fire, the capability of the foam to extinguish the same square footage of fire remains the same. The reason for the pressure drop is that the larger tip opening in the 95 gpm nozzle keeps the pressure from building up to that which occurs in the 60 gpm nozzle.

The data also shows that the 95 gpm nozzle/Akron 2900 eductor combination had 13 percent less nozzle pressure than the 60 gpm nozzle/LP-6 eductor combination, but it also had a 49 percent increase in flow rate. The lower pressure results in slightly less range, but the additional flow rate provides the capability to extinguish approximately 50 percent more fire area. At the reduced pressures, this combination will still have a range of 34 feet on straight stream and 28 feet on narrow fog.

5.3 Nozzle Evaluation

The results reported in References 1, 2 and 7 indicate that several commercial nozzles are superior to the Coast Guard nozzle and its fog applicator for firefighting. The commercial nozzles consistently provided the following:

a. straight streams with greater range,

b. fog patterns which were adjustable from narrow to wide fog without the need of an applicator,

c. wide fog patterns which both protect the operator and promote control and extinguishment,

d. the same flow rate on both its straight stream and fog patterns,

e. a flush setting for passing debris which in the Akron 3019 proved more successful than the Coast Guard nozzle and its applicator

f. superior protection in preventing heat flux from reaching the nozzle operator,

g. equivalent control and extinguishment times and cooling capabilities for compartment fires using only water, and

h. superior control and extinguishment times in controlling deck fires with water or AFFF solution.

Not all of the commercial nozzles are constructed of materials suitable for marine application. Of the commercial nozzles tested, two were judged to be satisfactory for service in a marine environment. Of the two, the Akron 3019 consistently ranked highest in the areas described above. In addition, it is apparent that considerable attention was given to human factors in its design because this nozzle was preferred by the nozzle operators for its ease and simplicity of operation. It is interesting to note that the Akron 3019 (95 gpm) nozzle can easily be converted into a 60 gpm nozzle (Akron 3019M) by using a hex screwdriver to remove the baffle spacer located inside the nozzle bumper (Figure 2). This feature provides a choice of either of two nozzles for the price of one.

6.0 DISCUSSION

Table 3A shows the performance characteristics of three nozzles rated for different flows when operating within the range of fire main pressures measured on the main deck of the different cutters. Table 3B shows the performance characteristics of several different nozzle/eductor combinations when operating at similar fire main pressures near the engine room. For a fire on the main deck, range would be a more important nozzle characteristic than for a fire in the engine room.

Pressure Measurements and Flow Calculations

At first glance the dynamic pressure and flow data for the three different nozzles (60,95, and 125 gpm) shown in Tables 3A and 3B might lead the nozzle operator to choose the 60 gpm nozzle, since it exhibited the highest nozzle pressure. Higher nozzle pressure does not necessarily mean greater extinguishing capability, however. Among the nozzles tested, the 60 gpm nozzle does

provide a higher pressure although not necessarily a greater range than the other two nozzles rated at higher flows of 95 and 125 gpm. Table 3A shows, however, that the 95 gpm nozzle and the 125 gpm nozzle respectively provide 43 percent and 60 percent more water than the 60 gpm nozzle at the existing pressures. As stated in Section 15, Chapter 6 of the NFPA handbook (Reference 11), it is flow and not pressure alone which extinguishes a fire. Therefore, some pressure can be sacrificed for greater extinguishing capacity. With this in mind, the 95 gpm nozzle can be considered a compromise that provides slightly less pressure (and range) but an increased flow rate and thus application rate.

A minimum foam application rate of 0.1 gpm/sg ft is recommended in Section 19, Chapter 4 of Reference 11 for extinguishing Class B fires. Consequently, a 60 gpm flow should extinguish a 600 square foot fire and a 95 gpm flow should extinguish a 950 square foot fire. Provided that the fire can be reached, it is logical to use a nozzle providing a flow rate which can extinguish a larger fire. Such a flow rate does not have to be provided continuously for it to be effective. Results of the compartment testing (Class B fuel) reported in Reference 8 indicate that the ideal extinguishing technique is to first get as close as possible to the fire and then extinguish it by using bursts of water rather than a continuous stream. With a high flow rate, the fire could be overpowered in a short time with a limited number of water bursts. Thus it would be logical to choose the 95 gpm nozzle because of its ability to provide a greater flow rate. A nozzle rated for 125 gpm would provide an even greater flow rate but the nozzle pressure would decrease to the point where the range would be ineffective.

Nozzle/Eductor Evaluation

There are several factors that must be considered in order to achieve optimum effectiveness of the nozzle/eductor combination.

(1) The vessel's fire main must provide adequate pressure and flow to the eductor, so that the eductor will be operating at or near its design point for the correct AFFF solution concentration.

(2) The nozzle and eductor should be flow-matched (i.e. with the same gpm rating).

(3) The nozzle must provide an adequate flow (fire extinguishing capacity) at a pressure which provides sufficient range to reach the fire.

An eductor should be designed for the available inlet pressure, the flow of the fire main system and the nozzle, and the desired percent AFFF solution concentration. The nozzle should have a designed flow similar to the eductor. A nozzle and eductor with matching design points and operating at these points will provide their maximum performance. Therefore, a nozzle and eductor matched to each other should be purchased and placed into operation at the same time in order that maximum nozzle/eductor performance is available for fire fighting and to prevent any confusion in matching nozzles to eductors.

The performance of an eductor will be ideal (in terms of flow and AFFF solution concentration) at only one specific inlet pressure (its design point). Each eductor will, however, perform adequately over a range of inlet pressures. The design of the eductor will determine the degree to which its performance suffers as inlet pressure changes. Generally, inlet pressures below the design point will provide less flow and an AFFF solution concentration above the design concentration, while inlet pressures above the design point will result in higher flows and an AFFF solution concentration which is below the design concentration.

It should be remembered that the eductor controls the flow rate through the system, whereas the size of the nozzle tip opening regulates the velocity of the flow. A nozzle rated for a greater flow than the eductor will provide less pressure but will pass the same flow that exits the eductor. A nozzle rated for less flow than the eductor will provide a high pressure and less flow than the eductor's capacity. If the pressure at the outlet side of the eductor becomes greater than 70 percent of its inlet pressure than the eductor will not pick up AFFF concentrate. For example, the 60 gpm nozzle when used with the Akron 2900 eductor would not draw AFFF concentrate because the nozzle's small tip opening created too much back pressure at the inlet side of the eductor.

Data in Reference 3 indicates several eductors for a 95 gpm nozzle which would function over the range of inlet pressures (87-140 psig) measured on the cutters. The Akron 2900 eductor tested was rated at 90 gpm/200 psig/6 percent AFFF. These design features made it similar to the other eductors tested in Reference 3. Although these eductors produce a slightly higher flow rate (95 gpm) than the Akron 2901 eductor (70 gpm) at the inlet pressures measured on the cutters, they are still designed to produce a 6 percent AFFF solution at a 95 gpm flow. Since on cutters the inlet pressure is insufficient to provide this flow, the AFFF solution concentration would thus be above 6 percent. In this case the Akron 2901 eductor with its lower design inlet pressure (125 psig) for 70 gpm and a 6 percent AFFF solution would provide AFFF solution concentrations closer to 6 percent

than the eductors tested in Reference 3. The other eductor manufacturers could possibly modify their eductors for the lower inlet pressures on the cutters and thus provide a 6 percent AFFF solution with the available flow rates. The Akron 3019 nozzle design rated for 95 gpm at 100 psig with the LP-6 eductor will provide the same fire extinguishing application rate as a 60 gpm nozzle with the LP-6 eductor. With the 95 gpm nozzle, there will be a reduction in range because of less nozzle pressure, but this range would still be sufficient to reach the fire in the scenario being considered. The LP-6 eductor (with a design rating of 150 psig/55 gpm/6 percent AFFF) is not designed to provide the design flow of a 95 gpm nozzle (rated to flow 95 gpm at 100 psig). When the design flow (55 gpm) of the eductor is passed through a 95 gpm nozzle, the nozzle is passing only 58 percent of its design flow at an operating pressure of approximately 33 psig. The nozzle is in effect passing all the water discharged to it by the eductor but the nozzle's tip opening (designed for 95 gpm) is preventing a pressure build-up, thus reducing its range.

It is impractical and would be confusing to have the federal stock system contain the numerous nozzles and eductors needed so that an ideal combination would be possible for each pressures/flow condition measured on the different Coast Guard cutters. A more practical approach is to select a nozzle/eductor combination designed near the upper limit of the existing inlet pressures measured on the Coast Guard cutters. This would be a nozzle rated at 95 gpm and an eductor which has an inlet pressure design point of approximately 135 psig. This nozzle/eductor combination would provide approximately 42 psig and 61 gpm at the nozzle for the Coast Guard cutters measured to have the lowest inlet pressures and would also provide approximately 60 psig and 74 gpm at the nozzle for the Coast Guard cutters measured to have the greatest inlet pressures.

The AFFF percent solution concentration through such an eductor (i.e., the Akron 2901) would vary slightly on each Coast Guard cutter but it would still range within the acceptable limits for handlines listed in Reference 10.

7.0 CONCLUSIONS

1. For extinguishing Class B engine room fires, the overall performance and features of the Akron 3019 nozzle (rated at 95 gpm/100 psig) made it the most effective nozzle tested. Each Coast Guard cutter tested should be provided with the Akron 3019 and an in-line eductor matched to the nozzle and the available pressure of each cutter's fire main. The eductor should be required to discharge a 6 percent AFFF solution concentration at the inlet pressure developed by the fire main of the cutter. Since fire main pressures vary from cutter to cutter no one eductor will provide a 6 percent AFFF solution concentration on all of them. A solution is the Akron 2901 eductor which, as

shown in Table 3B, delivers acceptable AFFF solution concentrations (5.9 to 7.1 percent) and good flows (61 to 74 gpm) for the range of pressures recorded on the different cutters.

2. For extinguishing deck fires on each Coast Guard cutter tested, the Akron 3019 was also the most effective nozzle. Table 3A shows that for the pressures available from the fire mains, the Akron's 95 gpm rating also gave it superiority over other discharge ratings because of its capability to discharge the greatest quantity of water for the greatest distance.

3. Table 1 shows the pressure/flow characteristics for the fire main systems aboard different Coast Guard cutters and a P250 pump. The pressure/flow characteristics of the fire main systems varied considerably between different cutters but was insignificant between the test hydrants on the same cutter.

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APPENDIX A - DATA FOR CGC GALLATIN (WHEC 721)

LENGTH: 378 feet

No. of Fire Pumps: 3

Locations: Forward of Engine Room (4-99-0), Starboard side of Engine Room (4-215-1), Port side of Engine Room (4-215-2)

Manufacturer: Colt Industries Model: Capacity: 500 gpm @ 100 psig

Nozzle Location: 5 feet above hydrant

Hydrant Location: Main Deck, forward (1-69-2)

Pump Location: Engine Room (4-215-2)

Nozzle	Rating (gpm/psig)	Hose Length (ft.)	Eductor	Static Hydrant (psig)	Pressure Nozzle (psig)	Dynamic Hydrant (psig)	Pressure Nozzle (psig)	Nozzle Flow (gpm)	AFFF Concentration (%)
Akron 3019M	60/100	100	-	116	114	96	85	55	-
	60/100	100	LP-6	116	114	100	52	46	7.2
Akron 3019	95/100	100	-	116	114	88	70	79	-
	95/100	100	LP-6	116	114	100	22	44	7.5
Akron 3019	95/100	100	Akron 2900	116	114	87	40	60	9.0

Nozzle Location: 7 feet above hydrant

Hydrant Location: Main Deck, adjacent to Engine Room (1-208-1)

Pump Location: Inside Engine Room (4-215-2)

Nozzle	Rating (gpm/psig)	Hose Length (ft.)	Eductor	Static Hydrant (psig)	Pressure Nozzle (psig)	Dynamic Hydrant (psig)	Pressure Nozzle (psig)	Nozzle Flow (gpm)	AFFF Concentration (%)
Akron 3019M	60/100	100	-	105	102	90	80	54	-
	60/100	100	LP-6	105	102	93	48	42	7.8
Akron 3019	95/100	100	-	105	102	84	68	78	-
	95/100	100	LP-6	105	102	84	22	44	7.5
Akron 3019	95/100	100	Akron 2900	105	102	90	42	61	8.8

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APPENDIX B - DATA FOR CGC SENECA (WMEC 906)

LENGTH: 270 feet
No. of Fire Pumps: 2
Locations: Forward of Engine Room (3-86-0), Aft of Engine Room (3-197-0)
Manufacturer: Worthington Model: D1161 Capacity: 500 gpm @ 125 psig

Nozzle Location: 2 feet above hydrant
Hydrant Location: Main Deck, forward (1-24-1)
Pump Location: Forward of Engine Room (3-86-0)

Nozzle	Rating (gpm/psig)	Hose Length (ft.)	Eductor	Static Pressure Hydrant (psig)	Static Pressure Nozzle (psig)	Dynamic Pressure Hydrant (psig)	Dynamic Pressure Nozzle (psig)	Nozzle Flow (gpm)	AFFF Concentration (%)
Akron 3019M	60/100	100	-	111	110	105	96	59	-
	60/100	100	LP-6	111	110	107	52	43	7.7
Akron 3019	95/100	100	-	111	110	100	82	83	-
	95/100	100	LP-6	111	110	108	25	48	6.9
Akron 3021	125/100	100	-	111	110	95	72	106	-
	125/100	100	LP-6	111	110	108	22	59	5.6
Akron 3019M	60/100	100	Akron 2900	111	110	104	76	52	*
Akron 3019	95/100	100	Akron 2900	111	110	108	42	63	8.6
Akron 3021	125/100	100	Akron 2900	111	110	106	28	63	8.6

Nozzle Location: 5 feet above hydrant
Hydrant Location: Main Deck, close to Engine Room (1-46-01)
Pump Location: Forward of Engine Room (3-86-0)

Akron 3019M	60/100	100	-	110	108	110	102	61	-
	60/100	100	LP-6	110	108	106	52	43	7.7
Akron 3019	95/100	100	-	110	108	102	82	83	-
	95/100	100	LP-6	110	108	106	22	44	7.5
Akron 3021	125/100	100	-	110	108	102	72	107	-
	125/100	100	LP-6	110	108	106	22	59	5.6
Akron 3019M	60/100	100	Akron 2900	110	108	106	78	53	*
Akron 3019	95/100	100	Akron 2900	110	108	106	46	64	8.4
Akron 3021	125/100	100	Akron 2900	110	108	106	28	66	8.2

Nozzle Location: 5 feet above hydrant
P250 Pump/Fantail = Gale Products (Outboard Marine Corp.) 250 gpm @ 100 psig

Akron 3019M	60/100	100	-	110	108	110	102	61	-
	60/100	100	LP-6	108	106	106	52	43	9.3
Akron 3019	95/100	100	-	110	108	102	82	83	-
	95/100	100	LP-6	106	104	106	22	44	9.1
Akron 3021	125/100	100	-	110	108	102	72	107	-
	125/100	100	LP-6	110	108	106	22	59	6.8
Akron 3019M	60/100	100	Akron 2900	106	104	106	78	53	*
Akron 3019	95/100	100	Akron 2900	106	104	106	46	64	7.8
Akron 3021	125/100	100	Akron 2900	110	108	106	28	66	6.1

* = would not draw AFFF

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APPENDIX C - DATA FOR CGC WESTWIND (WAGB 281)

LENGTH: 269 feet
No. of Fire Pumps: 3
Locations: Port side of B-1 Engine Room (5-62-2), Port side of B-2 Engine Room (5-93-2)
Starboard side of B-2 Engine Room (4-111-1)
Manufacturer: PACO Model: Capacity:300 gpm @ 100 psig

Nozzle Location: Same height as hydrant
Hydrant Location: Main Deck, forward (1-34-1)
Pump Location: Port side of B-1 Engine Room (5-62-2)

Nozzle	Rating (gpm/psig)	Hose Length (ft.)	Eductor	Static Pressure Hydrant (psig)	Static Pressure Nozzle (psig)	Dynamic Pressure Hydrant (psig)	Dynamic Pressure Nozzle (psig)	Nozzle Flow (gpm)	AFFF Concentration (%)
Akron 3019M	60/100	50	-	114	114	111	110	63	-
	60/100	100	-	114	114	112	105	61	-
	60/100	100	LP-6	114	114	112	55	44	7.5
Akron 3019	95/100	100	LP-6	114	114	114	22	45	7.3
Akron 3019M	60/100	100	Akron 2900	114	114				*
Akron 3019	95/100	50	-	114	114	105	95	98	-
	95/100	100	-	114	114	106	90	90	-
	95/100	100	Akron 2900	114	114	112	55	70	7.7

Nozzle Location: Same height as hydrant
Hydrant Location: 02 deck close to B-3 Engine Room (2-137-2)
Pump Location: Port side of B-1 Engine Room (5-62-2)

Nozzle	Rating (gpm/psig)	Hose Length (ft.)	Eductor	Static Pressure Hydrant (psig)	Static Pressure Nozzle (psig)	Dynamic Pressure Hydrant (psig)	Dynamic Pressure Nozzle (psig)	Nozzle Flow (gpm)	AFFF Concentration (%)
Akron 3019M	60/100	50	-	114	114	110	107	62	-
	60/100	100	-	114	114	114	105	61	-
	60/100	100	LP-6	114	114	114	57	46	5.2
Akron 3019	95/100	50	-	114	114	105	95	93	-
	95/100	100	-	114	114	107	90	90	-
	95/100	100	LP-6	114	114	118	22	45	5.3
Akron 3019	95/100	100	Akron 2900	114	114	112	55	70	7.7

* = would not draw AFFF

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APPENDIX D - DATA FOR CGC VIGOROUS (WMEC 627)

LENGTH: 210 feet

No. of Fire Pumps: 2 Locations: Reefer Space (3-156-2), Engine Room (3-126-1)

Manufacturer: Aurora Model: 413 Capacity: 250 gpm @ 121 psig

Nozzle Location: 9 feet above hydrant

Hydrant Location: Main Deck (01-10-2)

Pump Location: Reefer Space (3-156-1)

Nozzle	Rating (gpm/psig)	Hose Length (ft.)	Eductor	Static Pressure Hydrant (psig)	Static Pressure Nozzle (psig)	Dynamic Pressure Hydrant (psig)	Dynamic Pressure Nozzle (psig)	Nozzle Flow (gpm)	AFFF Concentration (%)
Akron 3019M	60/100	50	-	122	118	107	100	60	-
	60/100	50	LP-6	122	118	112	51	43	7.7
	60/100	100	LP-6	122	118	112	50	42	7.9
Akron 3019	95/100	50	-	121	117	86	75	82	-
	95/100	50	LP-6	121	117	112	21	44	7.5
	95/100	100	LP-6	121	117	112	22	45	7.3
Akron 3021	125/100	100	LP-6	122	118	112	13	45	7.3
Akron 3019M	60/100	100	Akron 2900	122	118	109	80	54	*
Akron 3019	95/100	50	Akron 2900	122	118	103	50	67	8.1
	95/100	100	Akron 2900	122	118	103	50	67	8.1
Akron 3021	125/100	100	Akron 2900	122	118	104	31	70	7.7

Nozzle Location: 12 feet above hydrant

Hydrant Location: Adjacent to Engine Room (2-146-2)

Pump Location: Reefer Space (3-156-1)

Nozzle	Rating (gpm/psig)	Hose Length (ft.)	Eductor	Static Pressure Hydrant (psig)	Static Pressure Nozzle (psig)	Dynamic Pressure Hydrant (psig)	Dynamic Pressure Nozzle (psig)	Nozzle Flow (gpm)	AFFF Concentration (%)
Akron 3019M	60/100	50	-	128	123	114	105	62	-
	60/100	50	LP-6	128	123	119	58	46	7.1
	60/100	100	LP-6	128	123	119	57	45	7.3
Akron 3019	95/100	50	-	128	123	94	80	85	-
	95/100	50	LP-6	128	123	119	23	46	7.2
	95/100	100	LP-6	128	123	119	23	46	7.2
Akron 3021	125/100	50	-	128	123	80	55	93	-
	125/100	50	LP-6	128	123	117	14	47	7.0
	125/100	100	LP-6	128	123	119	15	48	6.9
CG APN **	55/100	100	LP-6	128	123	119	46	37	8.9
Akron 3019M	60/100	50	Akron 2900	128	123	115	88	56	*
	60/100	100	Akron 2900	128	123	115	85	55	*
Akron 3019	95/100	50	Akron 2900	128	123	111	54	70	7.7
	95/100	100	Akron 2900	128	123	111	54	70	7.7
Akron 3021	125/100	50	Akron 2900	128	123	111	34	73	7.4
	125/100	100	Akron 2900	128	123	111	34	73	7.4

* = would not draw AFFF

** = Coast Guard All-Purpose Nozzle

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APPENDIX E - DATA FOR CGC EVERGREEN (WMEC 295)

LENGTH: 180 feet
No. of Fire Pumps: 2
Locations: Motor Room (3-126-0), Engine Room (3-92-1)
Manufacturer: Gould Pump, Inc. Model: 3655 Capacity: 100 gpm @ 104 psig

Nozzle Location: 5 feet above hydrant
Hydrant Location: Main Deck, forward (1-44-2)
Pump Location: Engine Room (3-92-1)

Nozzle	Rating (gpm/psig)	Hose Length (ft.)	Eductor	Static Pressure Hydrant (psig)	Static Pressure Nozzle (psig)	Dynamic Pressure Hydrant (psig)	Dynamic Pressure Nozzle (psig)	Nozzle Flow (gpm)	AFFF Concentration (%)
Akron 3019M	60/100	50	-	111	109	104	98	59	-
	60/100	50	LP-6	111	109	104	63	48	6.9
	60/100	100	LP-6	111	109	104	61	47	7.0
Akron 3019	95/100	50	-	112	109	96	84	83	-
	95/100	50	LP-6	112	109	106	25	48	6.9
	95/100	100	LP-6	111	109	106	25	48	6.9
Akron 3019	95/100	100	Akron 2900	111	109	105	45	64	8.4

Nozzle Location: 5 feet above hydrant
Hydrant Location: Main Deck, close to Engine Room (1-92-1)
Pump Location: Forward of Engine Room (3-92-1)

Nozzle	Rating (gpm/psig)	Hose Length (ft.)	Eductor	Static Pressure Hydrant (psig)	Static Pressure Nozzle (psig)	Dynamic Pressure Hydrant (psig)	Dynamic Pressure Nozzle (psig)	Nozzle Flow (gpm)	AFFF Concentration (%)
Akron 3019M	60/100	50	-	112	110	98	94	58	-
	60/100	50	LP-6	112	110	103	62	47	7.0
	60/100	100	LP-6	112	110	104	61	47	7.0
Akron 3019	95/100	50	-	112	110	83	72	81	-
	95/100	50	LP-6	112	110	103	23	46	7.2
	95/100	100	LP-6	112	110	103	23	46	7.2
Akron 3019	95/100	100	Akron 2900	112	110	101	45	64	8.4

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APPENDIX F - DATA FOR CGC RED WOOD (WLM 685)

LENGTH: 157 feet
No. of Main Fire Pumps: 1
Location: Engine Room (2-73-1)
Manufacturer: Ingersoll Rand   Model: Capacity: 250 gpm @ 125 psig

Nozzle Location: 12 feet below hydrant
Hydrant Location: 01 deck forward (01-2-0)
Pump Location: Engine Room (2-73-1)

Nozzle	Rating (gpm/psig)	Hose Length (ft.)	Eductor	Static Pressure Hydrant (psig)	Static Pressure Nozzle (psig)	Dynamic Pressure Hydrant (psig)	Dynamic Pressure Nozzle (psig)	Nozzle Flow (gpm)	AFFF Concentration (%)
Akron 3019M	60/100	100	-	135	140	128	120	66	-
	60/100	100	LP-6	135	140	134	81	54	6.1
Akron 3019	95/100	100	-	135	140	124	100	95	-
	95/100	100	LP-6	135	140	133	33	54	6.1
Akron 3019	95/100	100	Akron 2900	135	140	130	56	72	7.5

Nozzle Location: 5 feet below deck
Hydrant Location: Main Deck, close to Engine Room (1-42-0)
Pump Location: Engine Room (2-73-1)

Akron 3019M	60/100	100	-	138	140	125	114	64	-
	60/100	100	LP-6	138	140	134	81	54	6.1
Akron 3019	95/100	100	-	138	140	113	88	56	-
	95/100	100	LP-6	138	140	134	33	54	6.1
Akron 3019	95/100	100	Akron 2900	138	140	124	52	71	7.6

Pump P250 (Gale Products (Outboard Marine Corp.) 250 gpm @ 100 psig

Akron 3019M	60/100	100	-	110	110	100	94	58	-
Akron 3019	95/100	100	-	110	110	95	80	85	-

(Pump failed to operate for testing with eductors)

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APPENDIX G - CGC PENOBSCOT BAY (WTGB 107)

LENGTH: 140 feet
No. of Fire Pumps: 2
Locations: Engine Room (3-34-1), Engine Room (3-34-2)
Manufacturer: Deming Pump   Model: 3180 Capacity: 500 gpm @ 145 psig

Nozzle Location: 5 feet above hydrant
Hydrant Location: Main Deck, forward (1-3-2)
Pump Location: Engine Room (3-34-2)

Nozzle	Rating (gpm/psig)	Hose Length (ft.)	Eductor	Static Pressure Hydrant (psig)	Static Pressure Nozzle (psig)	Dynamic Pressure Hydrant (psig)	Dynamic Pressure Nozzle (psig)	Nozzle Flow (gpm)	AFFF Concentration (%)
Akron 3019M	60/100	100	-	158	156	140	126	67	-
	60/100	100	LP-6	158	156	146	80	54	6.1
Akron 3019	95/100	100	-	158	156	127	102	96	-
	95/100	100	LP-6	158	156	145	32	54	6.1
Akron 3019	95/100	100	Akron 2900	158	156	138	60	74	7.3

Nozzle Location: 5 feet above hydrant
Hydrant Location: Main Deck, adjacent to Engine Room (1-64-1)
Pump Location: Engine Room (3-34-2)

Nozzle	Rating (gpm/psig)	Hose Length (ft.)	Eductor	Static Pressure Hydrant (psig)	Static Pressure Nozzle (psig)	Dynamic Pressure Hydrant (psig)	Dynamic Pressure Nozzle (psig)	Nozzle Flow (gpm)	AFFF Concentration (%)
Akron 3019M	60/100	100	-	158	156	142	130	68	-
	60/100	100	LP-6	158	156	146	80	54	6.1
Akron 3019	95/100	100	-	158	156	132	108	98	-
	95/100	100	LP-6	158	156	148	32	54	6.1
Akron 3019	95/100	100	Akron 2900	158	156	140	60	74	7.3

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